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GB 2099263 A GB 2066629 A EP 0150082 A2

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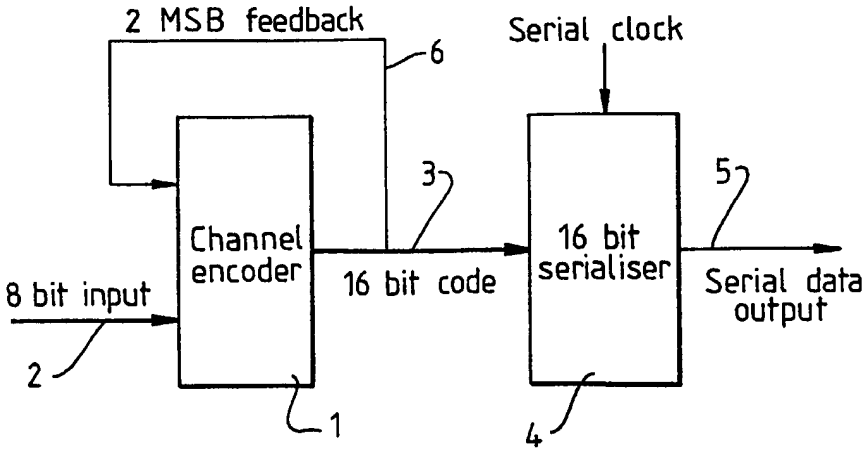
(54) Coding of digital signals

(57) A method of coding an input digital signal by replacing successive m-bit groups of the input signal with associated n-bit code words, where n is an even number greater than m, to produce an output signal, comprises: identifying a said n-bit code word associated with each said m-bit group, the code words being such that at least some of the 2^m possible m-bit groups each have a different complementary pair of said code words associated therewith and each code word is dc-free and has a predetermined maximum transition width of $\leq T_{max}$ bits and a minimum transition width between the first and last transitions therein of $\geq T_{min}$ bits; and selectively outputting either the identified code word or its complement in dependence upon the preceding output code word so that a serial bit stream formed of successive output code words has a minimum transition width of $\geq T_{min}$ and a maximum transition width of $\leq T_{max}$ even across the boundaries between successive code words. Applications include channel coding in video tape recorders.

FIG. 1



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.

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FIG. 1

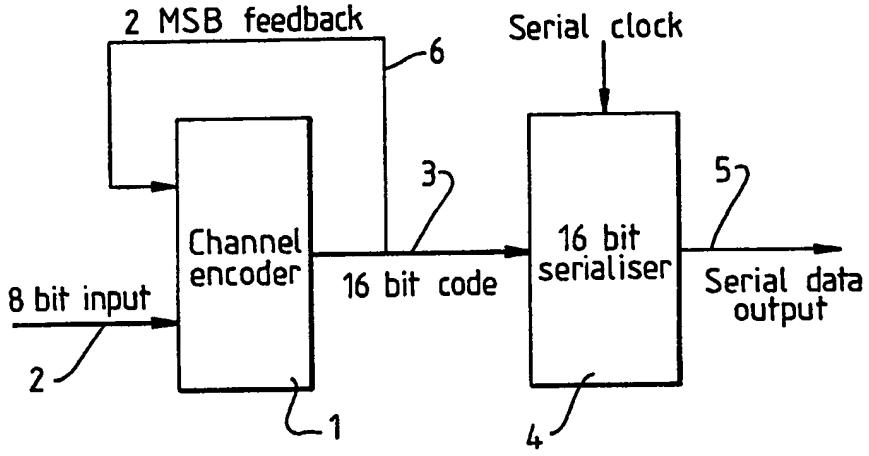

FIG. 2

Previous 2 MSB's	Current 2 LSB's	Output
00	00	Invert
00	01	True
00	10	Invert
00	11	True
01	00	Invert
01	01	Invert
01	10	True
01	11	True
10	00	True
10	01	True
10	10	Invert
10	11	Invert
11	00	True
11	01	Invert
11	10	True
11	11	Invert

CODING OF DIGITAL SIGNALS

This invention relates to coding of digital signals, and in particular, though not exclusively, to channel coding in DVTRs.

Channel coding is the conversion of real data into channel bits, ie code bits, so that the encoded data has more desirable characteristics. Channel coding of digital video signals is carried out to produce a signal which is more suitable for recording on magnetic tape. For example, real video data may contain long runs of continuous ones or continuous zeros. This is effectively a dc component of the video signal, and magnetic media will not respond to dc. Thus, an important quantity in an encoded signal is the maximum transition width. This is the largest number of bits between adjacent transitions in the signal or, in other words, the number of bits in the longest run of continuous ones or continuous zeros in the signal. As a further example, there is normally a frequency response limit in a replay channel so that replay of high-frequency components of a signal becomes unreliable. Thus, it is desirable to be able to limit the minimum transition width, ie the minimum period between adjacent transitions in the encoded signal, to the extent required in a given system.

Most coding, with the exception of Modified Miller code (M^2) does not take into account the effect on transition widths of running arbitrary code values end to end. M^2 does deal with this, but in a serial coding manner, that is to say the coding is affected on a bit-by-bit basis with respect to the real data. For practical design reasons, it is desirable to effect the coding on a word basis so that successive m-bit groups of real data are converted to n-bit code words using a conversion table or "codebook". Such codes often aim to achieve a balance of 1s and 0s in each code word thus ensuring a zero dc content. While such codes, known as block codes, are well known, the known codes often do not restrict the worst case bit run-lengths, and run-length violations may occur across the boundaries of code words. Where run-lengths are restricted, this is achieved in a complex manner.

According to the present invention there is provided a method of

coding an input digital signal by replacing successive m-bit groups of the input signal with associated n-bit code words, where n is an even number greater than m, to produce an output signal, the method comprising:

identifying a said n-bit code word associated with each said m-bit group, the code words being such that at least some of the 2^m possible m-bit groups each have a different complementary pair of said code words associated therewith and each code word is dc-free and has a predetermined maximum transition width of $\leq T_{max}$ bits and a minimum transition width between the first and last transitions therein of $\geq T_{min}$ bits; and

selectively outputting either the identified code word or its complement in dependence upon the preceding output code word so that a serial bit stream formed of successive output code words has a minimum transition width of $\geq T_{min}$ and a maximum transition width of $\leq T_{max}$ even across the boundaries between successive code words.

Thus, by requiring that each code word has a predetermined maximum transition width, ie T_{max}, and by considering the boundary between the preceding output code word and the next expected code word, the invention ensures that the worst case longest bit run-length in a serial data stream formed of successive code words is automatically limited to T_{max}. This has the desirable effect of limiting the low frequency content of the signal whilst the equal numbers of 1s and 0s in each code word ensures zero dc content. An m-bit group of the input signal can be replaced with either code word of an associated complementary pair of code words one of which is the binary complement of the other. At least one code word of the pair will provide a boundary with the preceding output code word which does not violate the maximum run-length requirement. In the same way, the invention enables the worst case minimum run-length or transition width in a serial-bit stream formed of successive output code words to be limited to a predetermined value, ie T_{min}. While $T_{min} = 1$ may be acceptable in certain cases, in general it is desirable for the minimum run-length to be greater than 1 bit so that the resulting coded signal has low spectral energy at high frequencies.

Selection of a particular code word or its complement is

preferably made in dependence upon the result of an analysis of the boundary region only between that code word and the preceding output code word. In the case where a serial bit stream is to be formed of successive output code words least significant bit first, the method preferably comprises analysing the 4-bit sequence formed of the two least significant bits of the said identified code word and the two most significant bits of the preceding output code word. Depending upon the result of this analysis, either the identified code word or its complement is output so that the serial bit stream has a minimum transition width of $\geq T_{min}$ and a maximum transition width of $\leq T_{max}$. Similarly, if a serial bit stream is to be formed of successive output code words most significant bit first, then the method preferably comprises analysing the 4-bit sequence formed of the two most significant bits of the said identified code word and the two least significant bits of the preceding output code word. In each case, therefore, a 4-bit sequence across the boundary between successive output code words in the serial bit stream to be formed is considered.

It is preferred that each said code word has a maximum run-length of $\leq T_{max} - 1$ bits within the T_{max} least significant bits and within the T_{max} most significant bits thereof. Where a 4-bit sequence across the boundary of successive code words is considered, this condition ensures that the maximum transition width condition can be met while one bit transition widths can be avoided in the said serial bit stream.

While the values of m and n may vary, a convenient value for m may be $m = 8$, for example in the case of an input video signal where the data comprises successive eight bit words. Similarly, the values of T_{max} and T_{min} may vary in dependence upon the particular requirements in a given case. However, at least in the case where $m = 8$, it is preferred that $T_{max} = 6$ and $T_{min} = 2$. Clearly the value of m sets certain constraints on the value of n since sufficient code words satisfying the various conditions, eg those relating to T_{max} and T_{min}, must be available. However, where $m = 8$ it is preferred that $n = 16$, this being the lowest value of n which allows all the aforementioned conditions to be satisfied.

It will be appreciated that the input and output signals may be in serial or parallel form. However, the input signal is conveniently

a parallel bit m-bit signal. Similarly, the output signal is conveniently a parallel bit n-bit signal. The output signal may be converted to serial form for recording on magnetic tape.

It is to be appreciated that the invention extends to apparatus adapted to perform the method as hereinbefore described. In general, where features are described herein with reference to a method of the invention, corresponding features may be provided in an apparatus in accordance with the invention and vice versa.

A preferred embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a block diagram of encoding apparatus embodying the invention; and

Figure 2 is a table used in describing the operation of the apparatus of Figure 1.

The embodiment of Figure 1 will be described with reference to the coding of an input parallel-bit digital video signal which is to be recorded on magnetic tape in a DVTR. The code to be described in this example is an 8-16 block code in which successive 8-bit groups of the input signal are converted to 16 bits prior to recording.

The apparatus of Figure 1 comprises a channel encoder 1 having an input 2 to which successive 8-bit words of the input parallel-bit video signal are supplied. The channel encoder 1 converts each 8-bit word of the input signal into a 16-bit code word which is supplied to an output 3 of the encoder 1. The output 3 is connected to a 16-bit serialiser 4 which converts successive 16-bit code words supplied thereto into serial form. Successive bits of the serial bit stream produced by the serialiser 4 are clocked along an output 5 of the serialiser by a serial clock as indicated in the figure. The serial data on the output 5 is supplied to a recording head (not shown) of the DVTR for recording on tape.

The channel encoder in this example comprises a PROM with a register which provides for feedback between the output and inputs of the encoder 1. In the figure, a 2-bit feedback bus 6 is shown connected to the output 3 of the encoder to feed back two bits of each output code word to the encoder inputs. In this example, recording is to be effected least significant bit first so that the serialiser 4 outputs the least significant bit of each 16-bit code word first, and

the two most significant bits of each 16-bit code word are fed back to the inputs of the encoder 1.

Each of the possible 2^8 bit patterns of the 8-bit input signal is associated with a different complementary pair of 16-bit code words in accordance with a codebook stored in the PROM of the encoder 1, though of course only one code word of each complementary pair need be stored in the PROM. Each of the code words is selected from the 2^{16} possible 16-bit combinations such that each code word has:

1. a maximum transition width of ≤ 6 bits;
2. a maximum run-length of ≤ 5 bits at the beginning and end thereof;
3. a minimum transition width between the first and last transitions therein of ≥ 2 bits; and
4. equal numbers of ones and zeros, ie dc balance.

Thus, for each input 8-bit word, there are two possible 16-bit codes, one being the binary complement of the other. Which code word of the pair is output depends upon the preceding output code word as described below.

When the first 8-bit word is supplied to the encoder 1, the encoder identifies the associated 16-bit code word stored in the PROM which is output along the bus 3 as the next 8-bit word is supplied to the encoder. The two most significant bits of the first output word are fed back via the bus 6 to the encoder inputs and stored in the register as the next 8-bit word is received by the encoder 1. The encoder 1 then identifies the 16-bit code associated with the input 8-bit word. The encoder 1 then checks the boundary between the identified code word and the previous output code word formed of the two most significant bits of the previous code word fed back along the bus 6 and the two least significant bits of the code word identified for the new input. The table of Figure 2 is then used to decide whether to output the identified code word or to invert this code word to form its binary complement.

Figure 2 shows all the possible bit patterns for the four bits across the code word boundary. The first column shows the values of the two most significant bits (MSBs) of the previous code word. The second column gives the values of the two least significant bits (LSBs)

of the currently identified code word. The third column indicates for each case whether the binary complement of the identified code word should be selected (INVERT) or the identified code word should be output without inversion (TRUE).

Use of the system tabulated in Figure 2 ensures that the serial bit stream on the output 5 of the serialiser 4 never has a transition width of greater than 6 bits or less than 2 bits. If the two MSBs of the preceding code word contain no transition, ie are of the same polarity, then the next code word to be output must change this polarity either at the LSB position or at the next bit, but an isolated one or zero across the boundary must be avoided. For example, considering the first entry in the table of Figure 2, the two MSBs of the previous code word are both zero so there could be a run-length of up to five zeros (the run-lengths at the beginning and end of each code are limited to five bits). Since the two LSBs of the identified code word are also both zero, the identified code word must be inverted to avoid the possibility of a run-length of more than six in the serial bit stream on the output 5. Considering the second entry in the table of Figure 2, again there could be a run-length of up to five zeros at the end of the previous code word, but there is only a single zero at the beginning of the currently identified code word. Since a run-length of six is allowable, this code word can be output without inversion. Taking the next entry in the table, there is no question of a run-length of more than six across the boundary, but the isolated one at the beginning of the current code word would violate the minimum transition width requirement in the serial output. Thus, the binary complement of this code word is output still without the possibility of violating the maximum run-length condition. All other entries in the table can be analysed in a similar manner.

Thus, it will be seen that with each code word satisfying conditions 1 to 3 listed above, either the code word stored in the PROM which is associated with a given input word or its complement will ensure that the minimum and maximum run-length conditions in the serial output are satisfied. Further, since each code word is in itself dc-free, the serial output will also be dc-free. The resulting encoded signal to be recorded on tape thus has low spectral energy at both high and low frequencies.

Of the 2^{16} possible 16-bit patterns, there are 268 complementary pairs of code words which satisfy conditions 1 to 4 listed above. These can be identified by performing a computer search. However, only 256 code pairs are required for implementation of the channel code with an 8-bit input. The 256 code pairs required can be selected so as, for example, to minimise the number of code words with a transition width of only two or to minimise the number of code words with a transition width of six. The codes are preferably selected to minimise the Digital Sum Variation (DSV). The DSV is zero at word boundaries (the codes are dc-free), but within the word boundaries the DSV varies between positive and negative maxima depending on the distribution of 1s and 0s within each code and the codes can be selected to minimise these DSV maxima.

Some codes may also be reserved for special purposes such as for encoding synchronisation data in the input signal. Alternatively, it may be desirable to encode synchronisation words using code words which do not satisfy all of the rules listed above. For example, in an input video signal with a 16-bit sync word, the sync word could be encoded as two 16-bit code words, one containing a run of seven zeros and the other containing a run of seven ones. Thus, although neither of the two sync code words is in itself dc-free, since they are used in pairs, there is overall dc balance in the serial output. This differentiation between codes for sync data and other data ensures that encoded video data cannot recreate the encoded sync pattern whereas this cannot be guaranteed if the same rules are applied to encoding of all input data.

CLAIMS

1. A method of coding an input digital signal by replacing successive m-bit groups of the input signal with associated n-bit code words, where n is an even number greater than m, to produce an output signal, the method comprising:

identifying a said n-bit code word associated with each said m-bit group, the code words being such that at least some of the 2^m possible m-bit groups each have a different complementary pair of said code words associated therewith and each code word is dc-free and has a predetermined maximum transition width of $\leq T_{max}$ bits and a minimum transition width between the first and last transitions therein of $\geq T_{min}$ bits; and

selectively outputting either the identified code word or its complement in dependence upon the preceding output code word so that a serial bit stream formed of successive output code words has a minimum transition width of $\geq T_{min}$ and a maximum transition width of $\leq T_{max}$ even across the boundaries between successive code words.

2. A method as claimed in claim 1, comprising analysing the 4-bit sequence formed of the 2 least significant bits of the identified code word and the 2 most significant bits of the preceding output code word and outputting either the identified code word or its complement in dependence upon the result of the analysis so that a serial bit stream formed of successive output code words least significant bit first has a minimum transition width of $\geq T_{min}$ and a maximum transition width of $\leq T_{max}$.

3. A method as claimed in claim 1, comprising analysing the 4-bit sequence formed of the 2 most significant bits of the identified code word and the 2 least significant bits of the preceding output code word and outputting either the identified code word or its complement in dependence upon the result of the analysis so that a serial bit stream formed of successive output code words most significant bit first has a minimum transition width of $\geq T_{min}$ and a maximum transition width of $\leq T_{max}$.

4. A method as claimed in any preceding claim, wherein each of the said code words has a maximum run length of $\leq T_{max} - 1$ bits within the T_{max} least significant bits and within the T_{max} most significant bits thereof.

5. A method as claimed in any preceding claim, wherein $T_{max} = 6$.

6. A method as claimed in any preceding claim, wherein $T_{min} = 2$.

7. A method as claimed in any preceding claim, wherein $m = 8$.

8. A method as claimed in claim 7, wherein $n = 16$.

9. A method as claimed in any preceding claim, wherein the said input signal is a parallel-bit m-bit signal.

10. A method as claimed in any preceding claim, wherein the said output signal is a parallel-bit n-bit signal.

11. A method of coding an input digital signal substantially as hereinbefore described with reference to the accompanying drawings.

12. Apparatus adapted to perform the method of any one of the preceding claims.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number

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Relevant Technical fields

(i) UK Cl (Edition K) H4P-PDD

(ii) Int Cl (Edition 5) H03M - 7/00, 7/22, 7/30

Search Examiner

S J DAVIES

Databases (see over)

(i) UK Patent Office

(ii)

Date of Search

21 JULY 1992

Documents considered relevant following a search in respect of claims 1-12

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2066629 A (SONY) - see eg Claim 1	
A	GB 2099263 A (SONY) - page 2, line 99 - page 5, line 12	
A	EP 0150082 A2 (PHILIPS) - page 1, line 1 - page 2, line 21	

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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